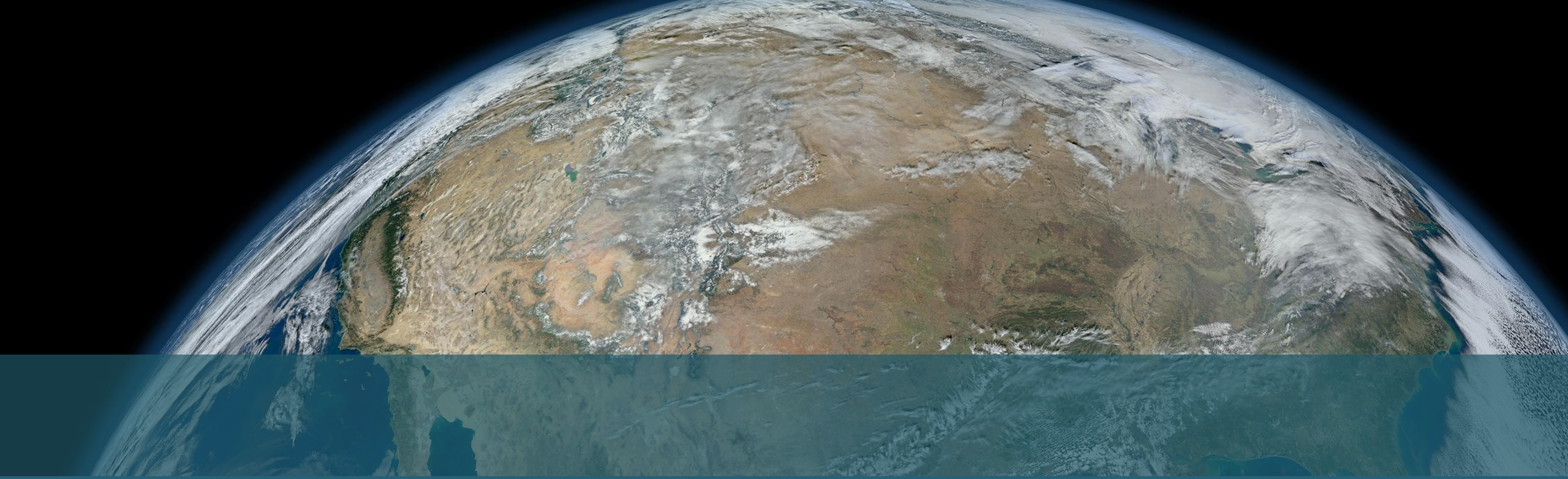


A real-time magnetic disturbance model to improve drilling accuracy in low and mid latitudes of the Earth

Manoj Nair, Adam Woods, Arnaud Chulliat, Patrick Alken and Nir Boneh
Thanks to Stefan Maus (MagVar), Benny Poedjono (Schlumberger)

ISCWSA | Houston | Oct 1, 2015

CIRES

NOAA Satellite and Information Service | National Centers for Environmental Information
University of Colorado | Cooperative Institute for Research in Environmental Sciences

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

Observed magnetic field at drill bit

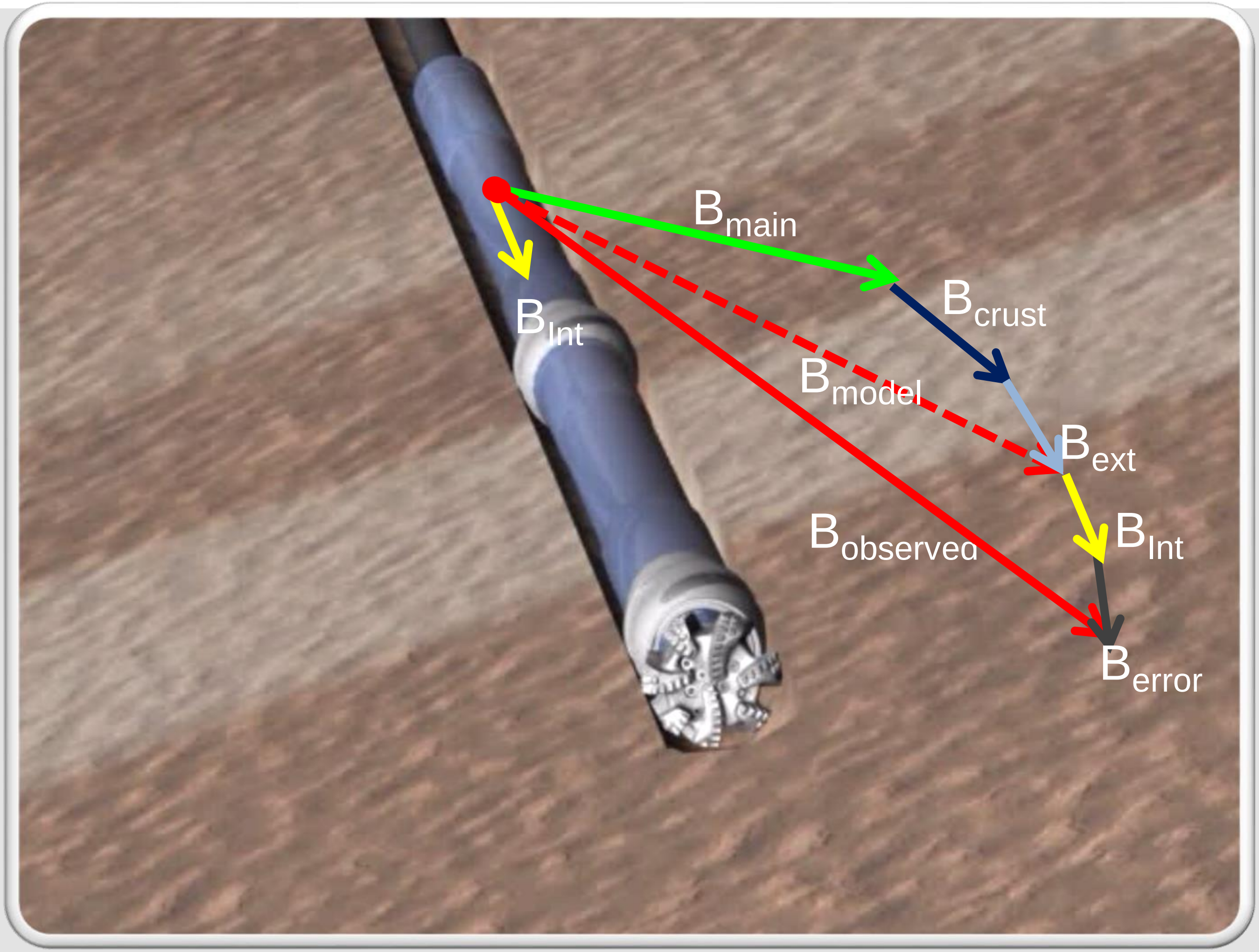


Image adapted from Schlumberger

Motivation

- NOAA’s magnetospheric real-time disturbance field calculator was presented at 2012 ISCWSA meeting at San Antonio.
- Updated the calculator to use latest USGS 1 minute Dst
- Validation against magnetic observatory and MWD data

Ref. Maus, S., Nair, M., Woods, A., Gannon, J. L., Finn, C. A. & Love, J. J., 2012. The NGDC/USGS real-time magnetospheric disturbance field calculator, ISCWSA, San Antonio, Texas.

Geomagnetic Field

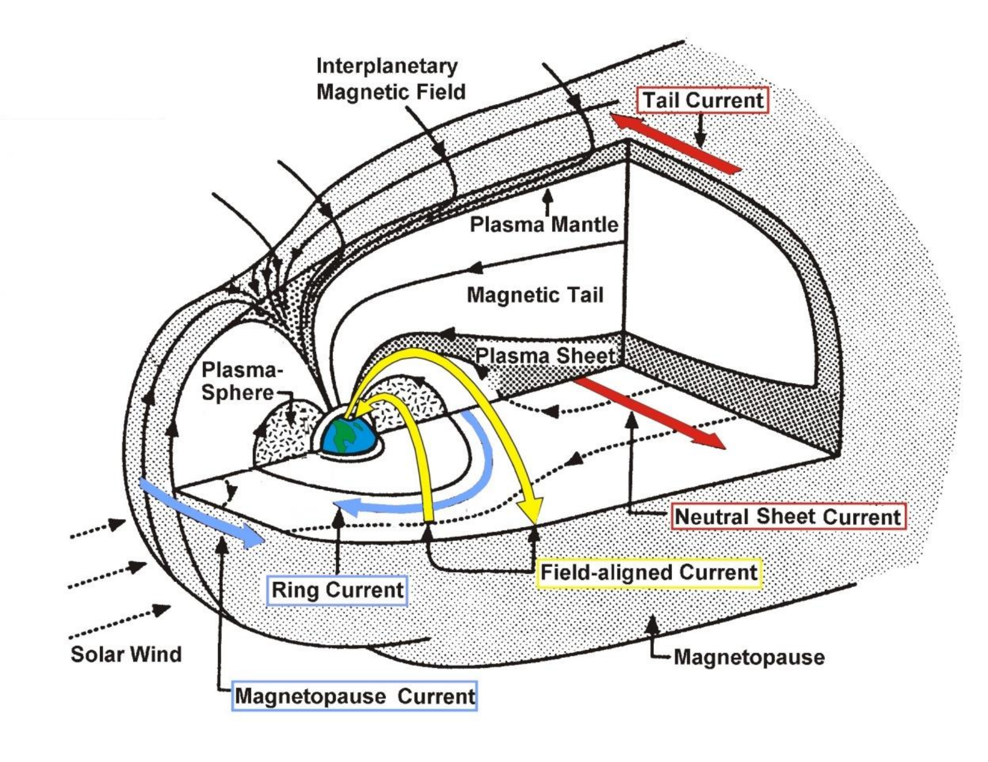
- Main field
  - Convection in the outer core
  - 95% of the observed strength
  - Secular variation
  - Data by satellite and observatories

- Crustal field
  - Magnetized rocks in the crust
  - Does not change with time
  - Data by satellite, ship and aircrafts

- External field
  - Currents in the magnetosphere and ionosphere
  - Disturbance by space weather
  - Upper atmospheric winds
  - Data by satellite and observatories

Magnetospheric currents and fields

Magnetospheric electric current systems



Use model of Maus & Lühr, 2005 & 2010

Real-time modeling of geomagnetic field

What is included

1. Magnetospheric variations caused by space weather
2. Rotation of the Earth in the magnetosphere
3. Secondary magnetic fields of electric currents, induced by time-varying magnetic fields in the conducting Earth and oceans

How

1. USGS real-time Dst* index (ground observatories), backup from WDC Kyoto
2. NASA solar wind measurements (ACE satellite)
3. Cloud based real-time modeling

**Dst = Disturbance Storm Time*

USGS Operational Dst

Derived from 4 geomagnetic observatories

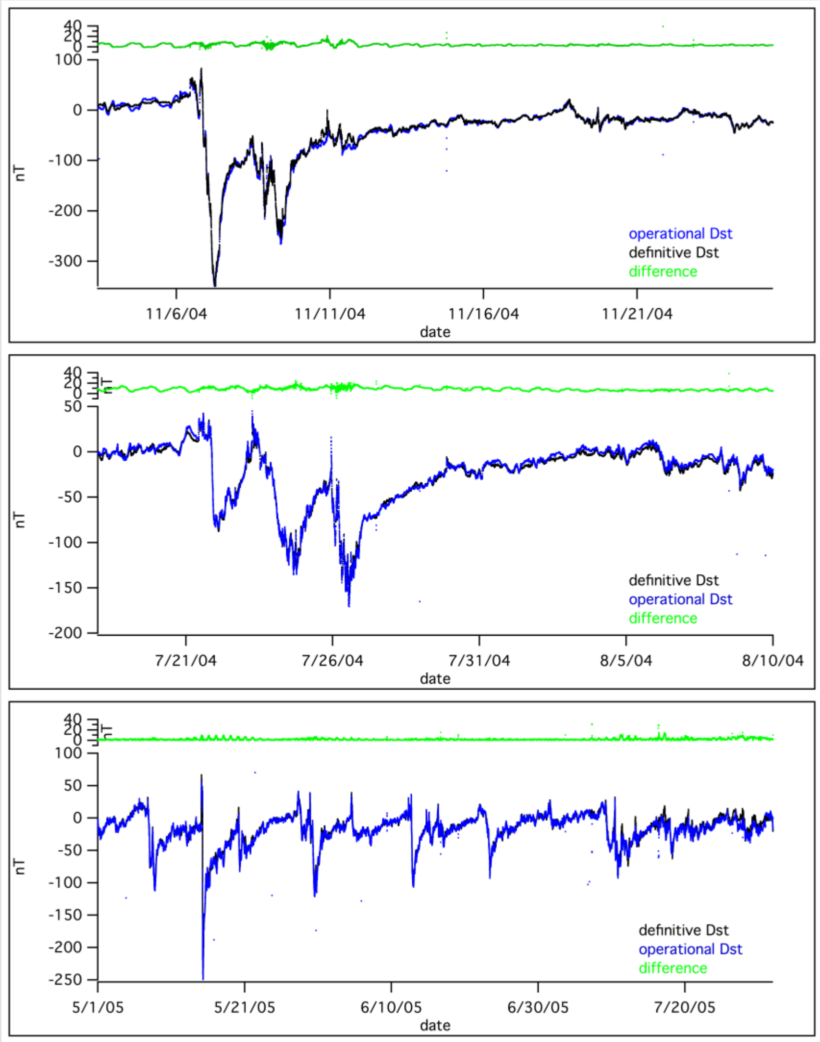
1 minute data

Real-time access

Latency 15 minutes

Backups USGS 3 station Dst and WDC Kyoto definitive Dst

Ref: Gannon, J. L. & Love, J. J., 2011. USGS 1-min Dst index, J. Atmos. Solar-Terr. Phys., 73, 323-334.



Separation of external component of Dst

Real-time Internal (Ist) and External (Est) Storm Time Indices

The Dst (Disturbance Storm Time) index is an index of geomagnetic activity derived from a global network of near-equatorial geomagnetic observatories that measures the intensity of magnetospheric "ring current". The time varying magnetospheric fields induce electric currents in the Earth which in turn give rise to a secondary internal field whose strength is roughly one third of the external field. Hence, the observed Dst index is the sum of the external source field and its induced counterpart. If the Earth were an ideal conductor then the two fields would be exactly in phase. For the real Earth, however, the phase lag and amplitude relation between the induced internal and inducing external field depends on the frequency content of the external source field. Dst is separated into internal storm time index (Ist) and external storm time index (Est) following Maus & Weidelt (GRL, Vol. 31, 2004). The one-minute real-time disturbance storm time index (Dst) is driven by the real-time Dst index provided by the USGS magnetic observatory network. The conductivity model used is the semi-global reference model, Model B, by Utada, Koyama, Shimzu and Chave (GRL, Vol. 30, 2003). Dst, Ist and Est data are available from 2013-11-01.

DST Input date

Start Date 03/16/2015

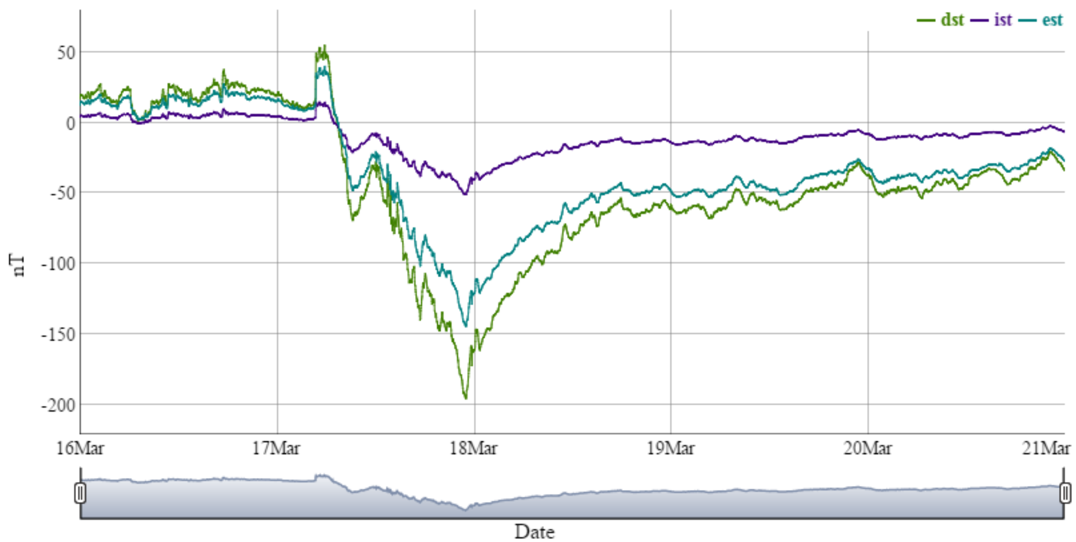
Start Time (UTC) 0

Number of days to calculate 5

Plot ☑ DST ☑ IST ☑ EST

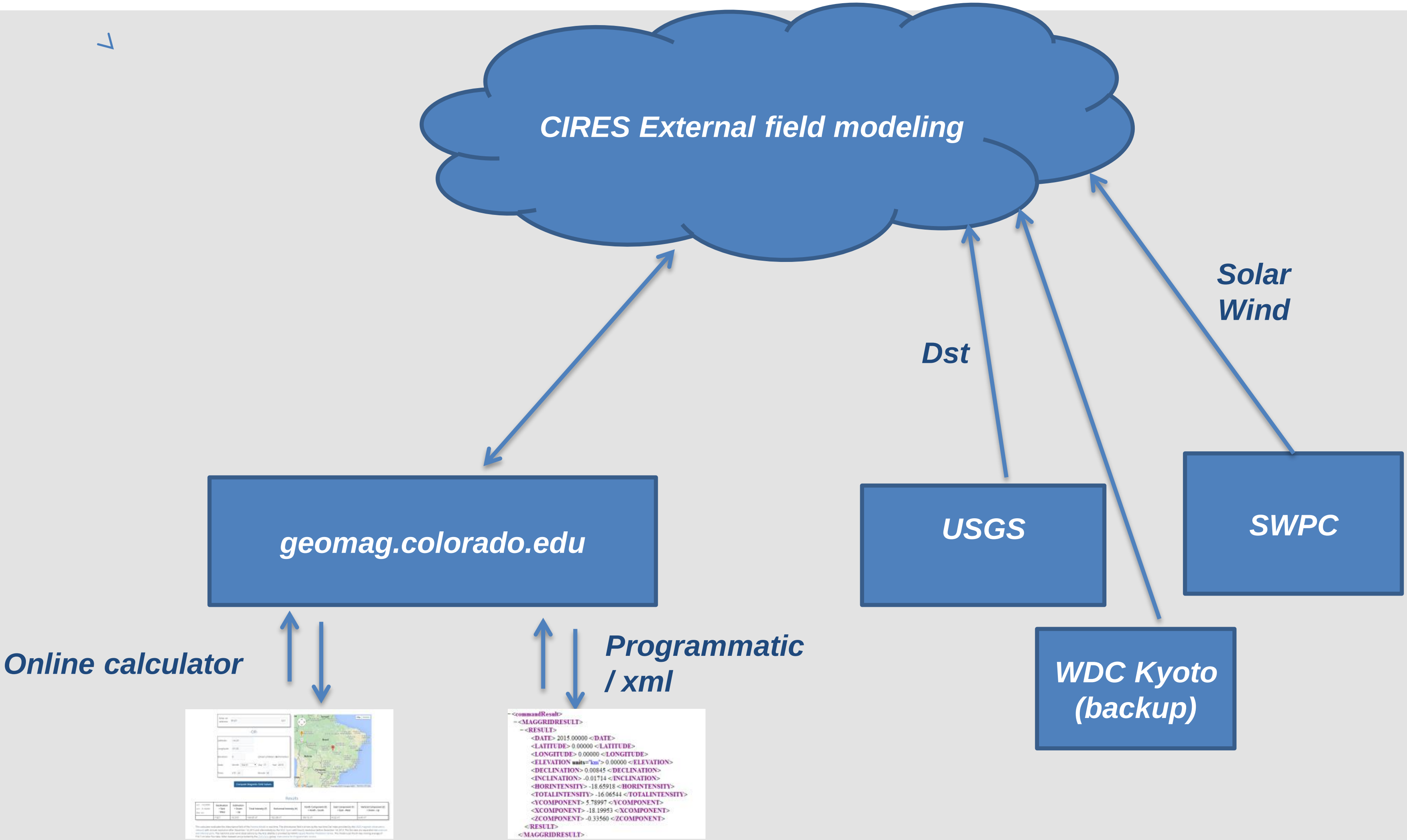
Submit

Download

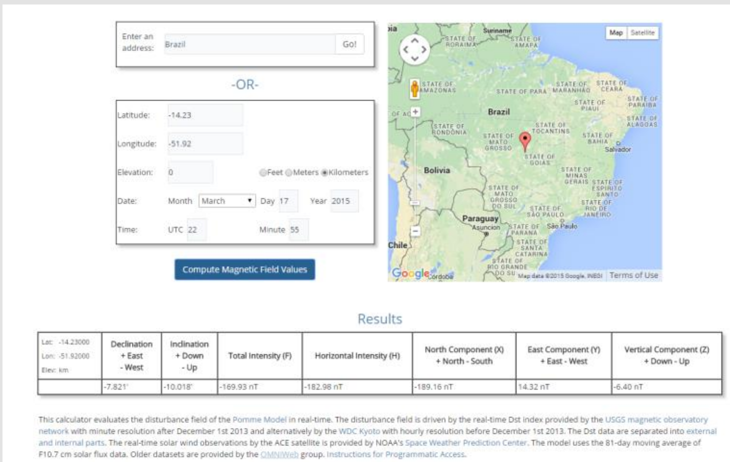


http://geomag.colorado.edu/rt-ist-est-storm-indices

Real-time modeling



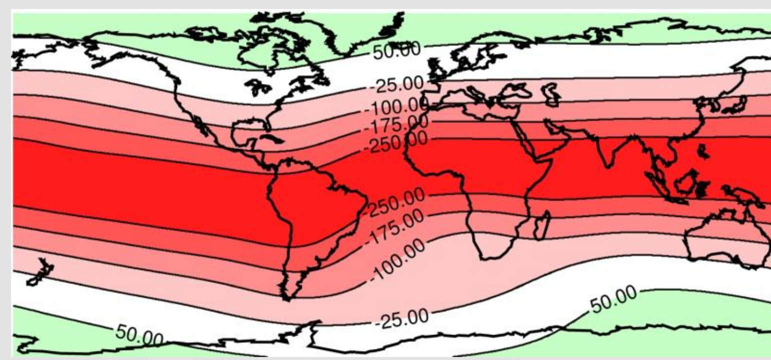
Screen shot of online calculator



Lat: -14.23000 Lon: -51.92000 Elev: km	Declination + East - West	Inclination + Down - Up	Total Intensity (F)	Horizontal Intensity (H)	North Component (X) + North - South	East Component (Y) + East - West	Vertical Component (Z) + Down - Up
	-7.821°	-10.018°	-169.93 nT	-182.98 nT	-189.16 nT	14.32 nT	-6.40 nT

This calculator evaluates the disturbance field of the Pomme Model in real-time. The disturbance field is driven by the real-time Dst index provided by the USGS magnetic observatory network with minute resolution after December 1st 2013 and alternatively by the WDC Kyoto with hourly resolution before December 1st 2013. The Dst data are separated into external and internal parts. The real-time solar wind observations by the ACE satellite is provided by NOAA's Space Weather Prediction Center. The model uses the 81-day moving average of F10.7 cm solar flux data. Older datasets are provided by the OMNIWeb group. Instructions for Programmatic Access.

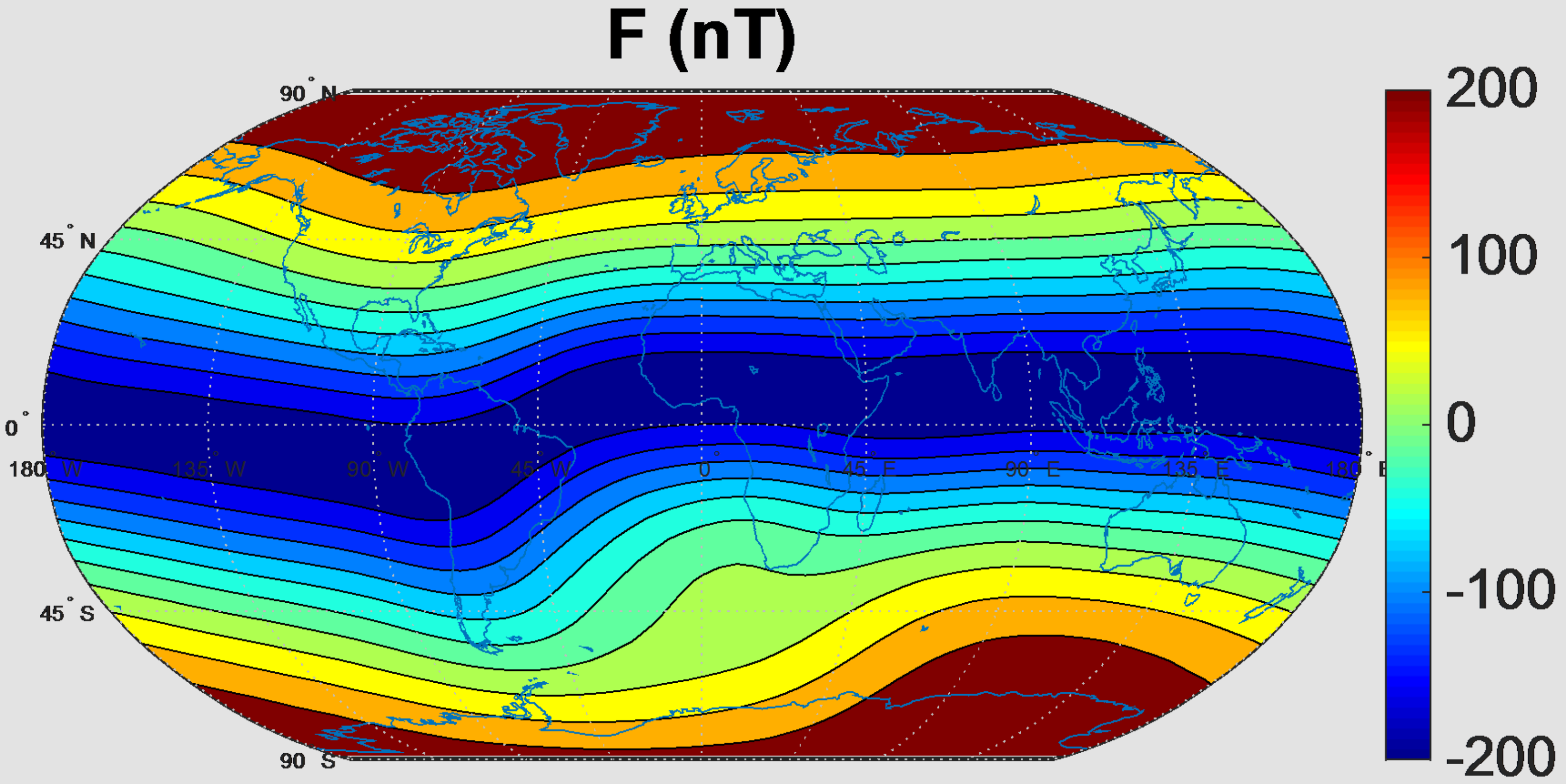
Total field at the Earth surface for a magnetic storm in October 2003



geomag.colorado.edu/real-time-disturbance-field-calculator

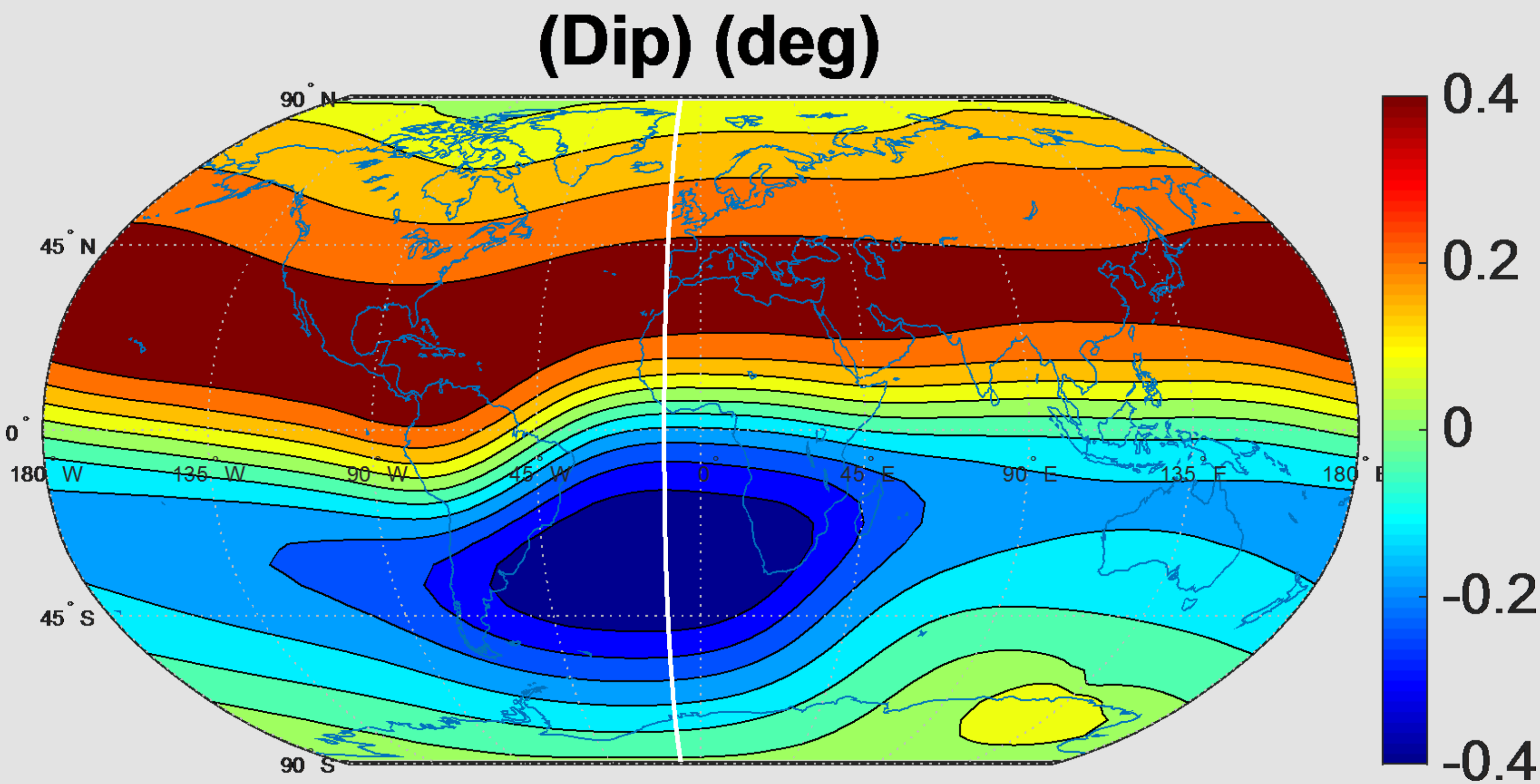
Minute resolution since December 2013. Hourly resolution for 2000-2013

Change in field strength



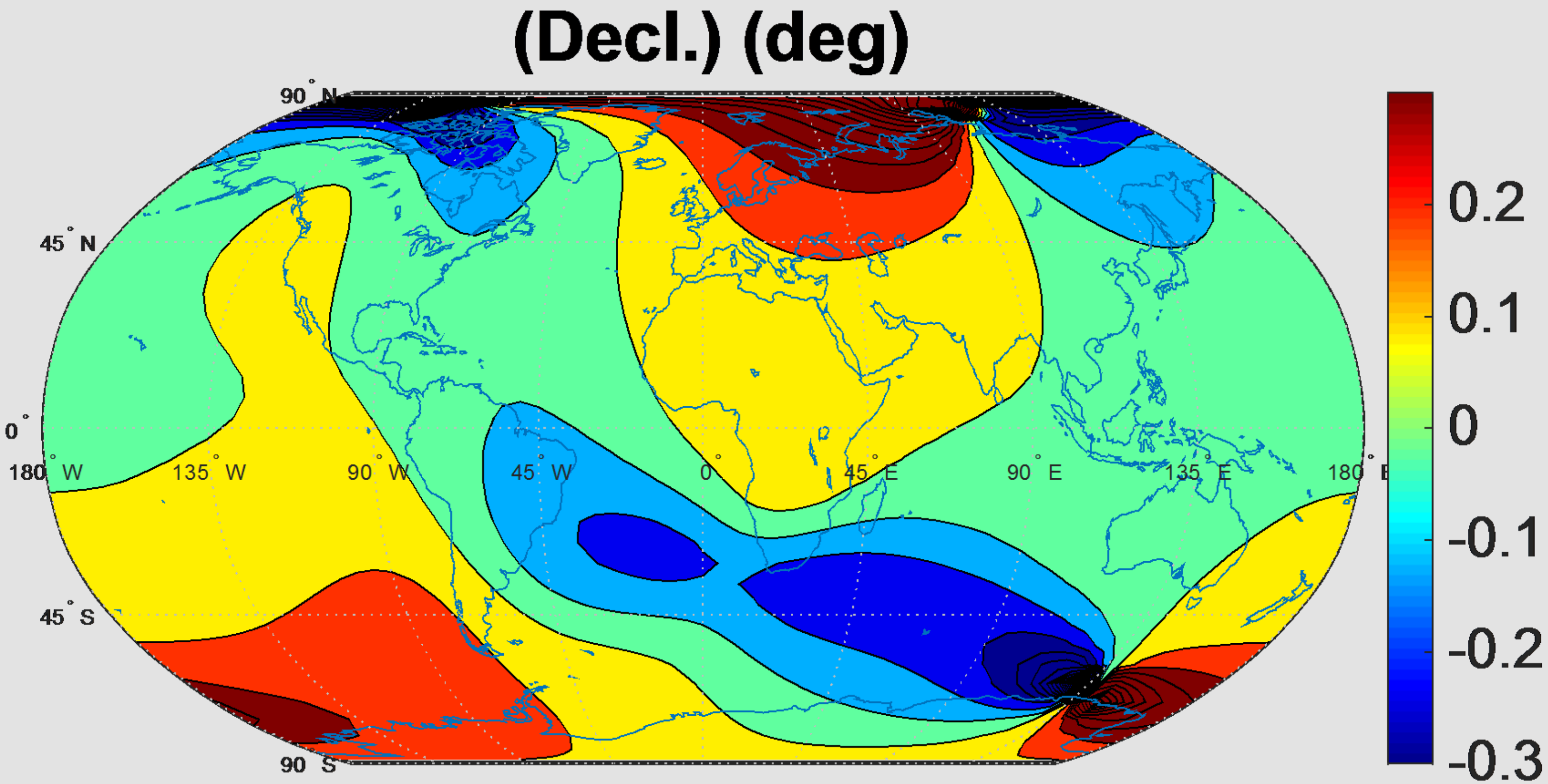
Magnetic storm on 2015-03-17 peak Dst (-194 nT)

Change in dip angle



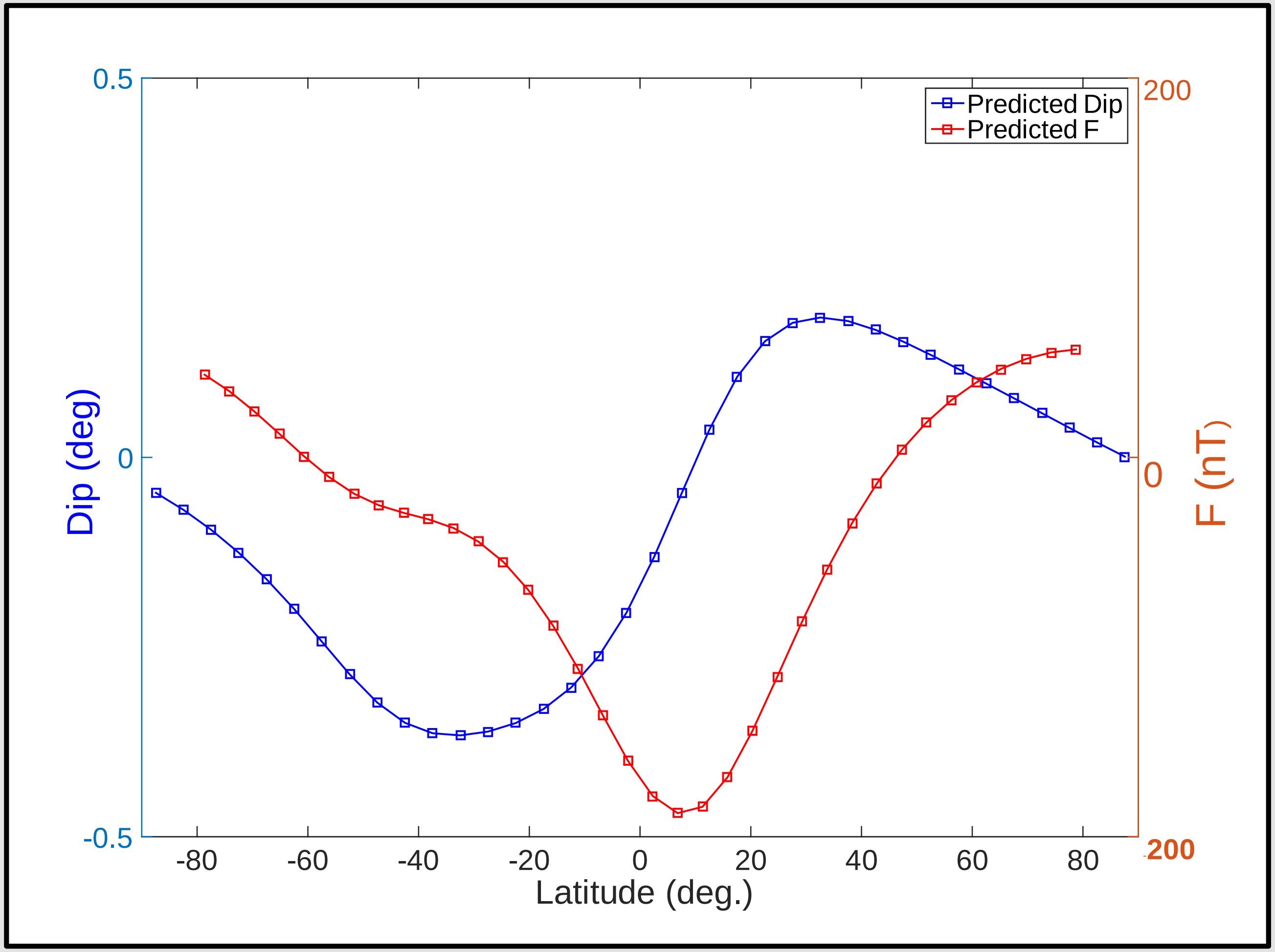
Magnetic storm on 2015-03-17 peak Dst (-194 nT)

Change in declination



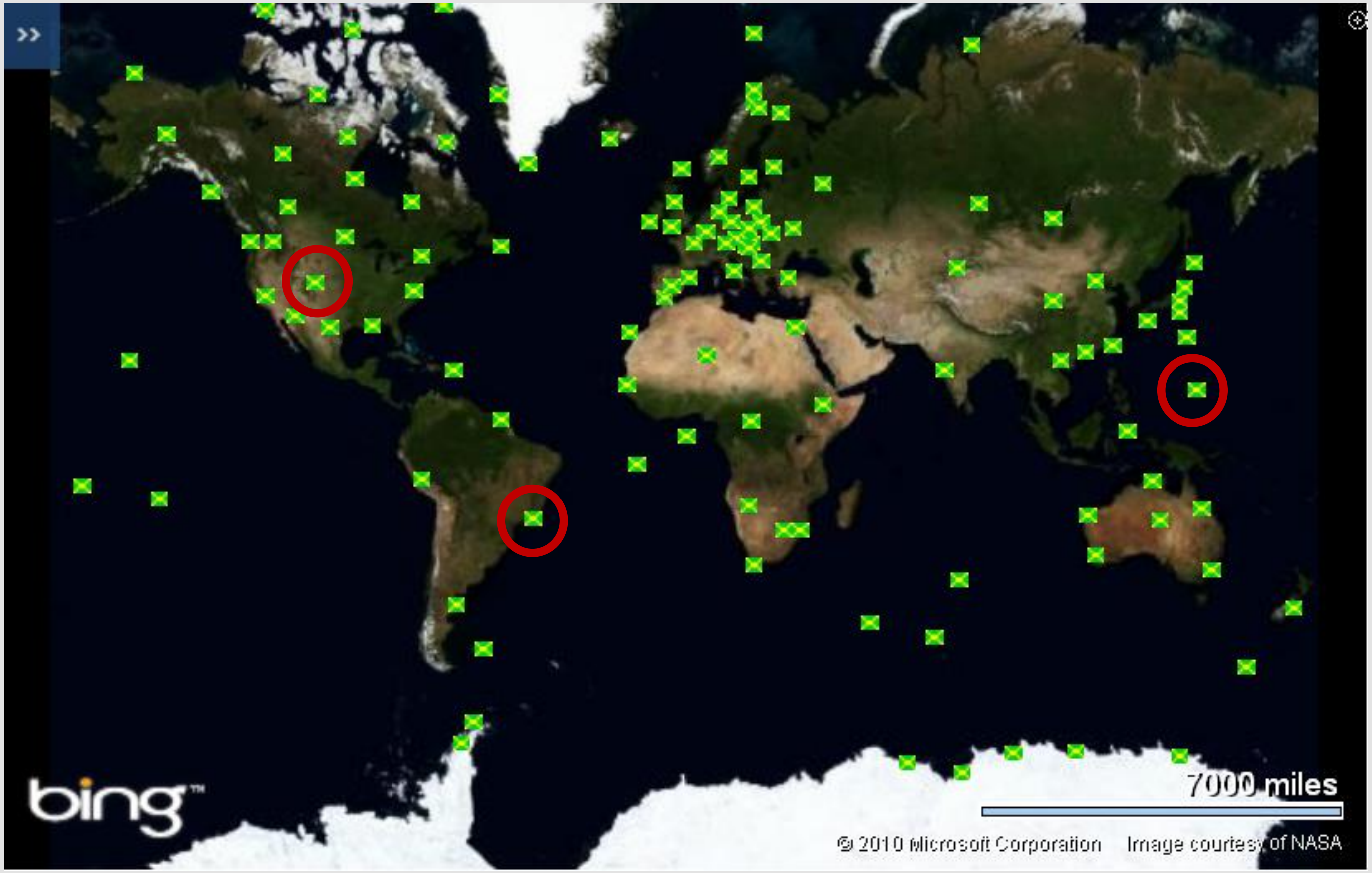
Magnetic storm on 2015-03-17 peak Dst (-194 nT)

NS profile at 10° W

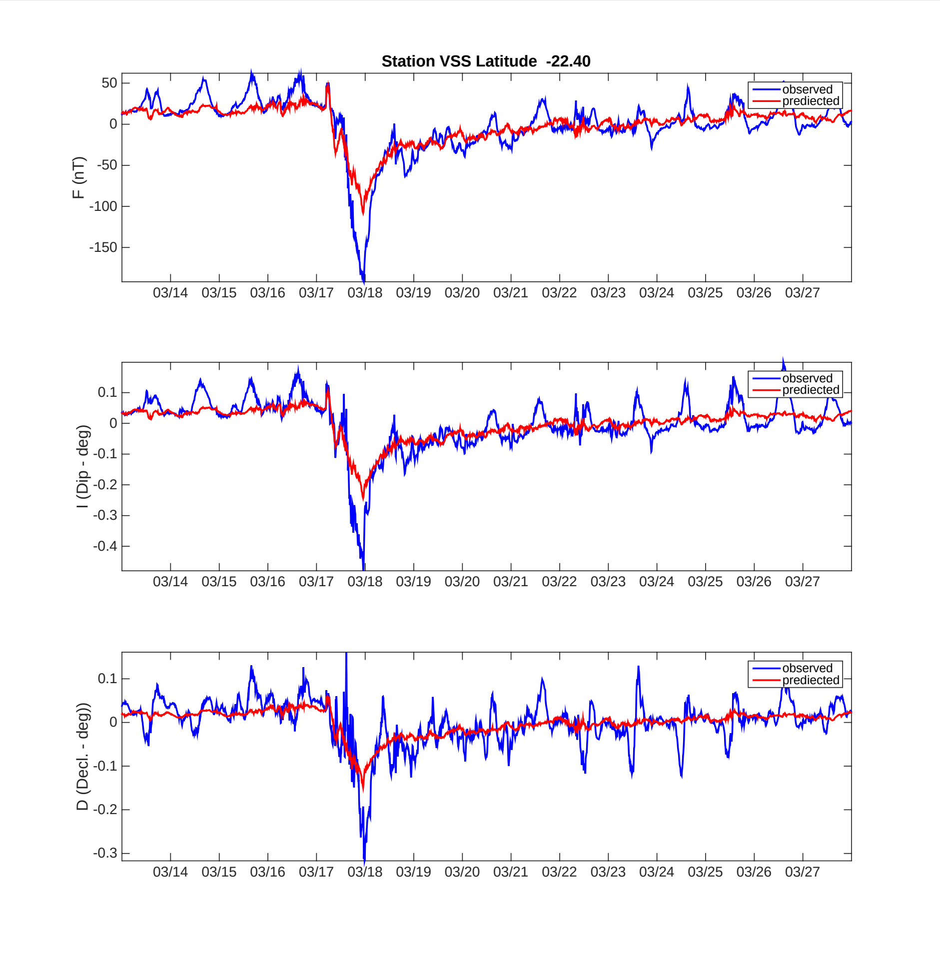


Magnetic storm on 2015-03-17 peak Dst (-194 nT)

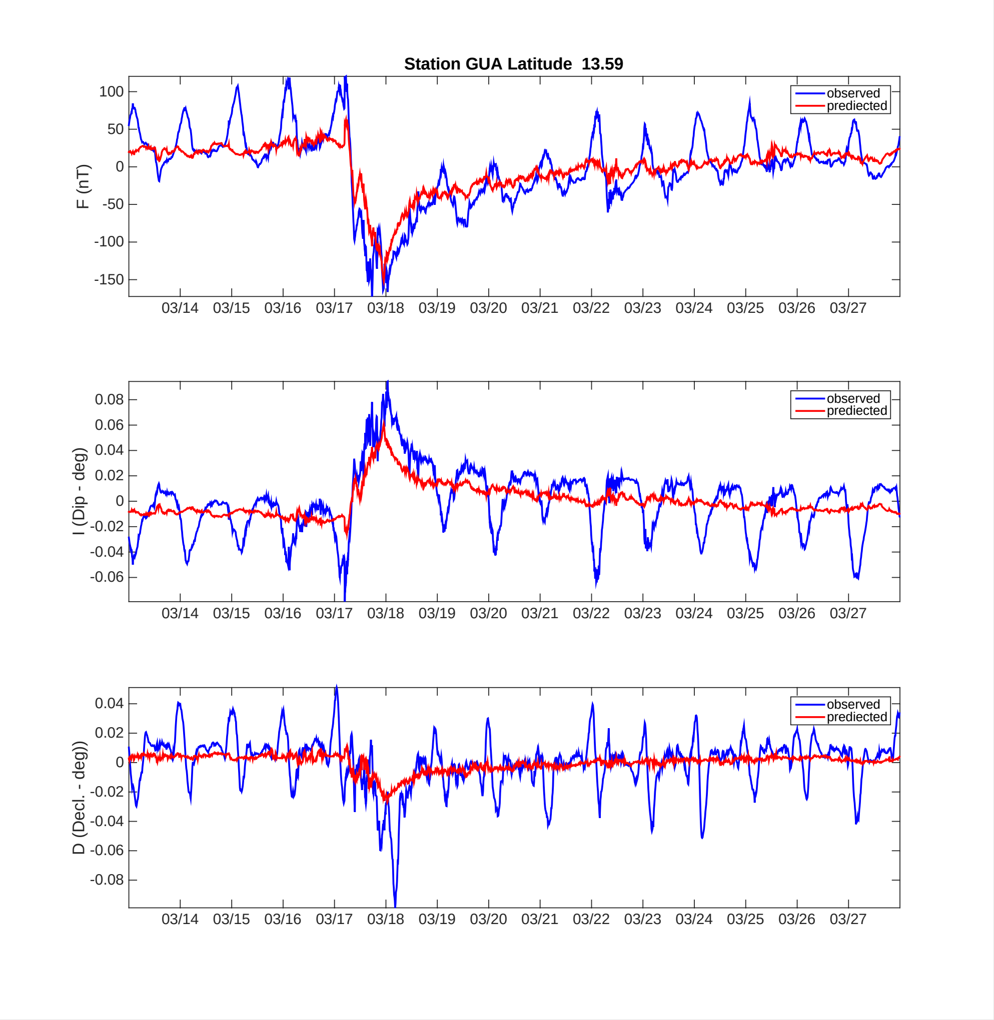
Validation with minute data



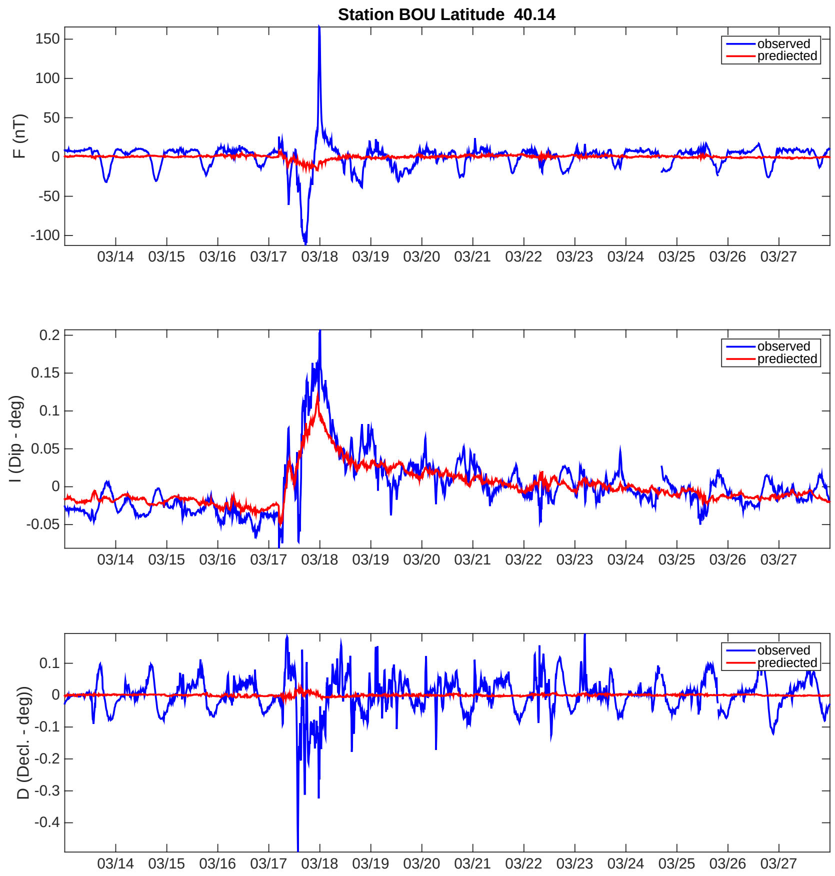
Station VSS Latitude -22.4°



Station GUA Latitude 13.59°



Station BOU Latitude 40.14°

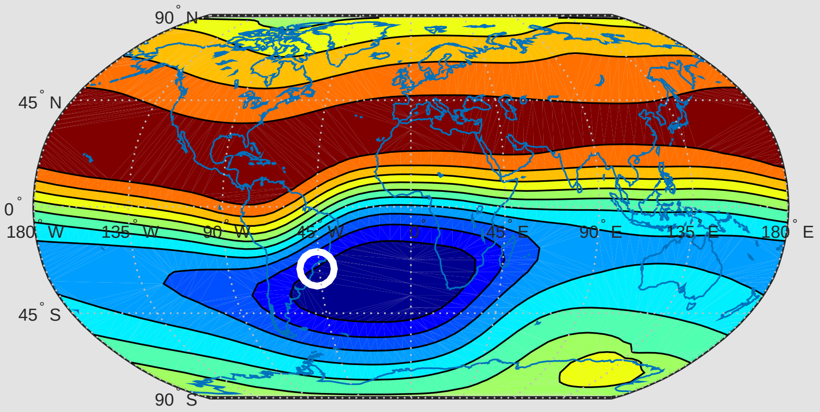


Validation with MWD data

Corrected for drill string interference from Schlumberger's MWD data from off Brazil during the March 17, 2015 magnetic storm.

A. HDGM2015 (Core, crust and average external)

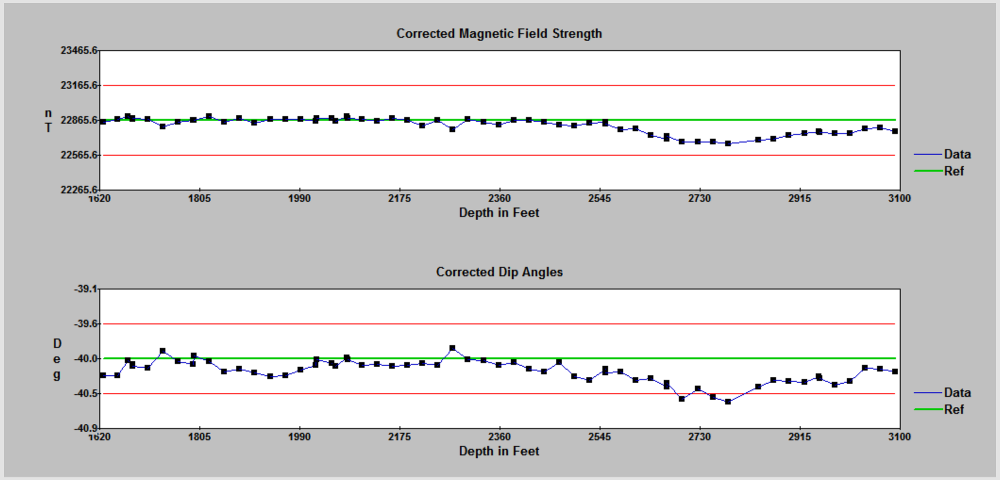
B. HDGM2015 (Core, crust) + Real-time disturbance model



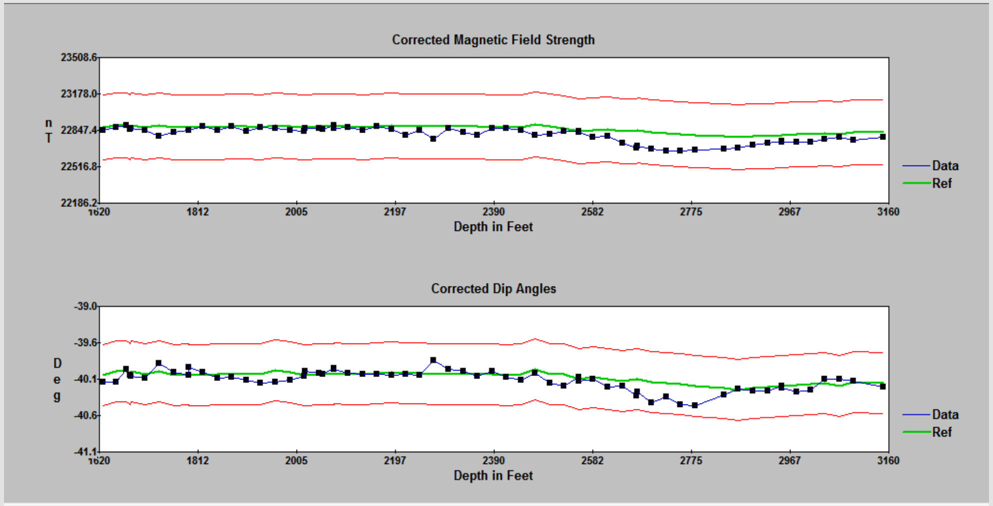
Correcting MWD data

Off Brazil

(March 15-18, 2015)



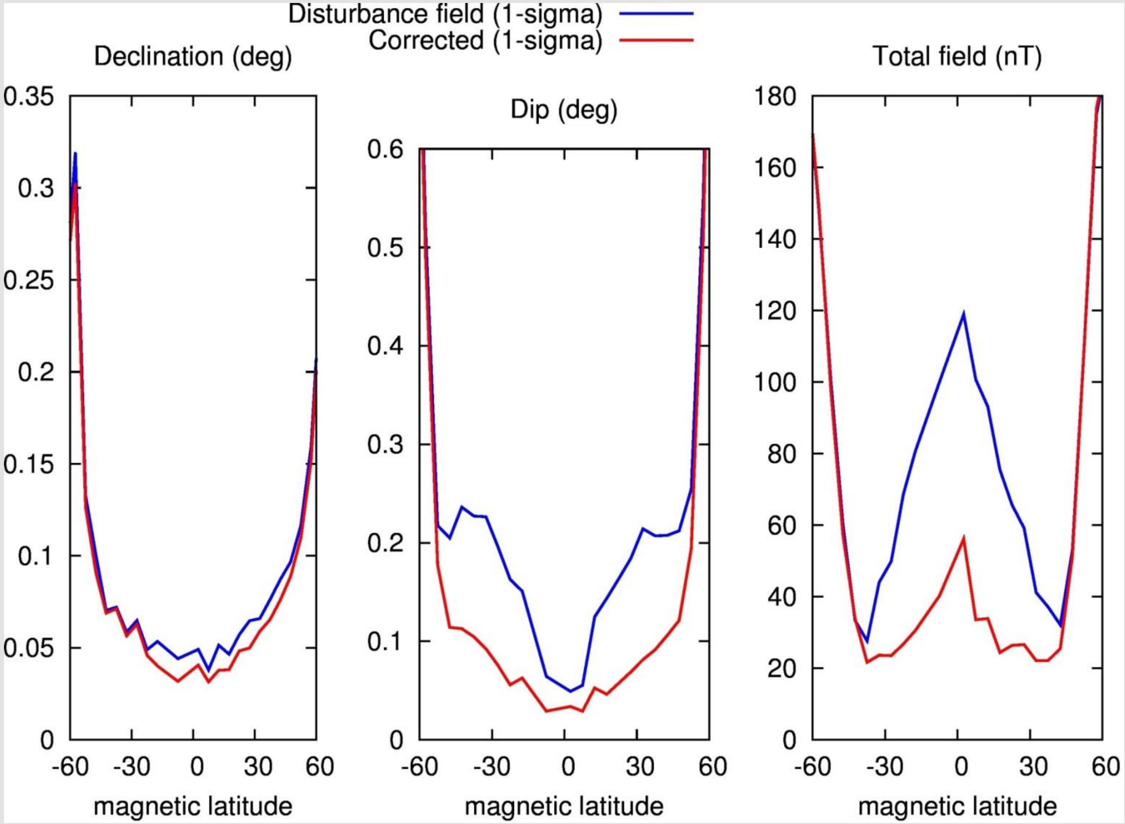
A. MWD vs HDGM
- Fix Reference



B. MWD vs HDGM RT
- Variable Reference
- Better fit

Image courtesy of Schlumberger

Disturbance During Magnetic Storms (Kp≥6)



Ref. Maus, S., Nair, M., Woods, A., Gannon, J. L., Finn, C. A. & Love, J. J., 2012. The NGDC/USGS real-time magnetospheric disturbance field calculator, ISCWSA, San Antonio, Texas.

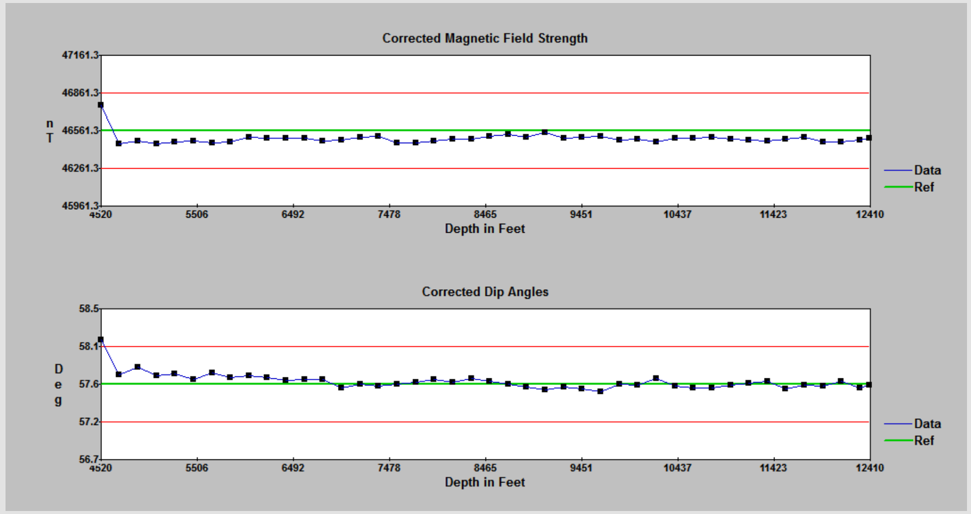
Summary

- **Magnetic disturbance field modeling**
  - Real-time modeling
  - Uses USGS operational Dst and ACE satellite IMF data as input
  - Available to public at geomag.colorado.edu
  - Manual and programmatic access
- **Works best in**
  - Up to 50% reduction in total field and dip residuals
  - Correct total field and dip for magnetic referencing
  - Preliminary validation with MWD data
- **Plans to improve**
  - Include further parts of the external field (Solar-quiet, electrojet)
  - 3D electromagnetic induction
  - Use solar-wind predicted Dst (30 minutes in advance)

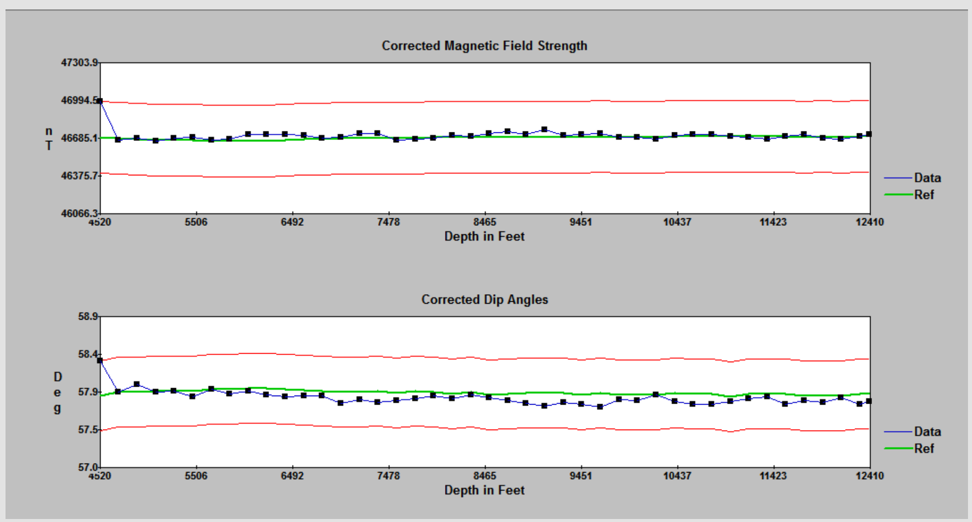
Correcting MWD data

South Texas – 1

(March 13-22, 2015)



A. MWD vs HDGM
- Fix Reference



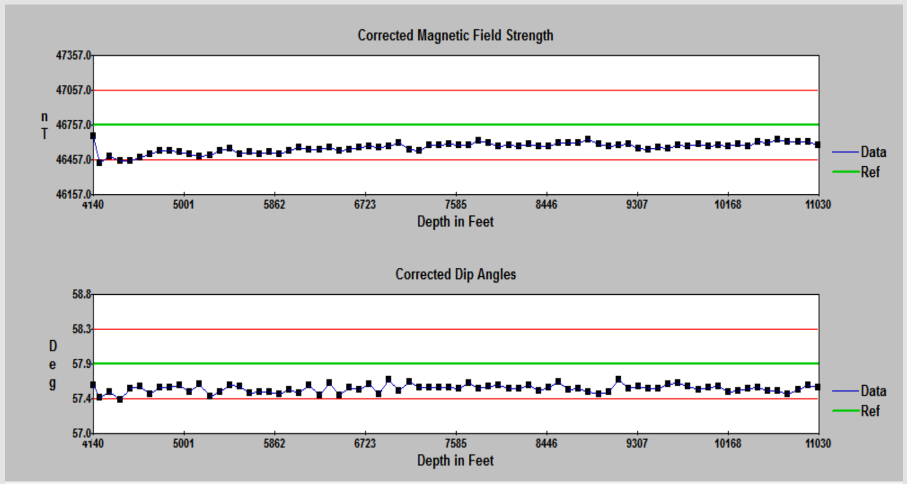
B. MWD vs HDGM RT
- Variable Reference
- Better fit

Image courtesy of Schlumberger

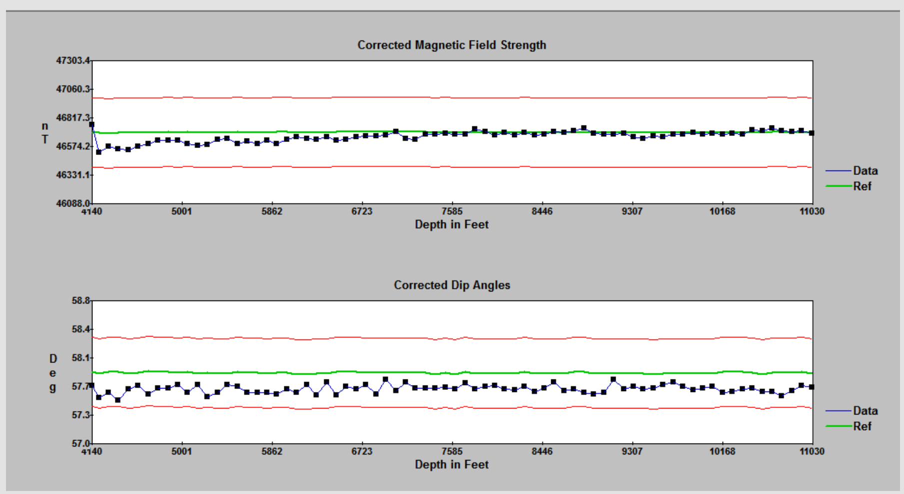
Correcting MWD data

South Texas – 2

(March 14-28, 2015)



A. MWD vs HDGM
- Fix Reference



B. MWD vs HDGM RT
- Variable Reference
- Better fit

Image courtesy of Schlumberger